Technology "make" and "buy" strategies and firm growth: firm-level evidence from Brazil

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1. Introduction

Technological progress is at the heart of development. But the innovation process in developing countries has very different characteristics from that in developed countries. Given the still wide technology gap developing countries are facing, the bulk of technological progress in these countries occurs through the absorption and adaptation of pre-existing technologies, rather than the invention of entirely new technologies. In addition, these pre-existing technologies are typically sourced from abroad.

A developing country's ability to absorb and adopt foreign technologies depends on two main factors: (i) the extent to which it is exposed to foreign technologies; this occurs mostly through trade, FDI and international migration of human capital and (ii) its ability to absorb and adapt those technologies to which it is exposed.

What matters most for technological development is the speed with which (foreign) technology diffuses within a country. Empirical evidence shows an important divergence across countries in the speed of diffusion within countries (World Bank, Global Economic Prospects 2008). Many developing countries have a business environment which constrains firm's absorption of new technologies and performance. Among the macro-factors identified as potential barriers are heavy regulatory burden, severe financial constraints and macro-economic uncertainty (Bastos and Nasir, 2004, Dollar et al., 2003, Eifert et al., 2005). However, what is still lacking is robust firm level evidence on what effectively drives, or hinders, firms in developing countries to adopt new technologies and effectively absorb them into a better firm performance.

To shed more light on the link between adoption of new technologies, innovation, productivity and firm growth in the context of a catching up economy, this paper analyses a sample of manufacturing firms from Brazil. In recent years, Brazil has been able to play an increasingly important role in international trade, production and (R&D) investment. Following a period of stabilization and trade liberalization in the 1990s Brazil has become internationally competitive in a number of sectors. Its export portfolio shows specialization in traditional sectors such as fresh and processed food products, leather and wood products, but also in a selected number of high-tech sectors, most notably the aerospace/regional jets (ITC, 2002). While this pattern of emerging success has given rise to a significant amount of research documenting the performance of the economy at the aggregate or sector level, the micro-evidence on the factors that underlie firm success is less abundant.

This paper, using data from the World Bank's Investment Climate Survey (ICS) data collected in Brazil in 2003, tries to contribute to the literature on technological progress and development in several ways.

- Because firms are the basic mechanism by which technology spreads within an economy, a micro-econometric perspective will allow investigating in more detail what drives or impedes firms to acquire and introduce technologies and how important these strategies are for innovative performance and firm growth.
- Our focus on Brazil allows analysing the case of a mid-income country in fast development, where the interplay between diffusion (buy) and creation (make) of new technologies, is centrepiece for sustaining growth.

- Also on the role of foreign technologies, trade and FDI, Brazil is an interesting case. Although it has recently opened up to the global economy, it still carries the reminders of a closed economy set-up, relying on its own large internal market, protecting "local champions" in strategic sectors, and with a strongly supported public sector R&D in specific technology and geographic areas.

Before we present our results in section 5, we first review several strands of the literature (section 2), discuss the specifics of Brazil (section 3) and present our data and methodology (section 4).

2. Literature review

We review several strands of the literature which are relevant for understanding the link between innovation and firm growth in developing countries.

2.1. Macro-economic literature on the role of innovation for development

A first macro-factor explaining cross-country differences in diffusion is the level of development. Technological diffusion is slow at very low levels of development, in part because of difficulties in affording new technologies, in part because low levels of human capital severely constrain technological progress. As the level of development rise, technological diffusion increases, particularly in percentage terms, because of the low base level. At some level of development, however, the pace of technological diffusion becomes less obvious, with a high cross-country variance in technology adoption, even across countries at similar development level. One explanation for this heterogeneity in diffusion rates at higher income levels is the divergence in the countries' ability to absorb new technologies. The speed with which a country absorbs and adopts technology depends on many factors, including the extent to which a country has a technologically literate workforce and a highly skilled elite; promotes an investment climate that encourages investment and permits the creation and expansion of firms using higher-technology processes; permits access to capital; and has adequate public sector institutions to promote the diffusion of critical technologies where private demand or market forces are inadequate.

Another explanation for the divergence in countries' performance on diffusion is a divergence in own indigenous innovative capacity, which becomes increasingly important as a country progress closer to the technology frontier. First, own R&D complements the adoption of existing technology because it is a component of absorptive capacity. Foreign technologies frequently need to be modified so that they are suitable for domestic circumstances. For example, equipment and processes may need to be adapted to differences in the quality of inputs and in the relative abundance of labor and capital, and a stock of researchers is often necessary to understand and evaluate advanced technology, particularly as the catching up process progresses and increasingly more advanced technologies need to be adopted. Countries tend to acquire technology more readily when domestic firms have R&D programs and when public research laboratories and universities have relatively close ties to industry (Maskus 2000). But, at higher levels of development, own R&D increasingly may also start to substitute adoption of existing technologies, allowing generation of new technologies, particularly in these areas where the country has developed some comparative strengths.

Overall, the macro-economic literature paints a complex relationship between technology make and buy along the development path of a country.

2.2. The effect of FDI on local firms' productivity: a review of the literature

Many endogenous growth models have emphasized technology spillovers from the North to the South as a vehicle for productivity growth of the South (e.g. Grossman and Helpman, 1991; Coe and Helpman, 1991). Among the channels of international technology diffusion, trade and FDI has been identified as the major contributor to the host economy's productivity growth with one of the most significant beneficial effects of foreign investment being related to technology spillovers across domestic firms and sectors. (e.g. Caves, 1974; Aitken and Harrison, 1999; Blomstrom and Kokko, 1997 for a review).

Industry and firm level studies focus on the issue of whether the presence of MNEs affects domestic firms' productivity. Earlier studies based on industry level cross-sectional data find a statistically significant horizontal spillovers effect both in host developed countries (Caves 1974, in Australia and Canada, Globerman 1979, in Canada) and developing countries (Blömstrom and Persson 1983, Blömstrom 1986, Kokko 1994 in Mexico). But cross-sectional studies typically overestimate the spillover effects of FDI because they are not able to control for firm or sector specific fixed effects. In a recent survey of studies using panel data sets, Görg and Greenaway (2003) find that only six studies for industrialized countries and none for developing countries report positive within-industry spillover effects.

One explanation for the difficulty to find evidence of positive spillovers is that spillovers from FDI are more likely to be vertical rather than horizontal in nature, since the latter have to account for the negative competitive effects (Markusen and Venables, 1999). But even if competition effects would be mute, as in vertical spillovers, the potential benefits from FDI may not materialize, since a critical factor to exploit spillovers is the technological capability of indigeneous firms (Blomström and Kokko, 1998). Most of the empirical studies on developing countries have failed to find robust evidence of positive knowledge spillovers from multinational investment, accounted for by the lack of absorptive capacity in these host countries (*e.g.* Aitken and Harrison, 1999).

2.3. Firm's innovation in developing countries

In developing countries, a majority of firms is operating far below the technological frontier, with lower levels of human capital and older vintage machinery. To raise efficiency or establish a better competitive position, firms' efforts are oriented towards developing capabilities to absorb, adapt and master technologies often developed elsewhere in a process of technological learning. Cohen and Levinthal (1989) developed the concept of 'learning' or 'absorptive' capacity to refer to firm's capabilities to identify, assimilate and exploit externally available information. Several authors (eg. Enos, 1992, Lall, 1992, among others, see also UNCTAD 1996 for an overview) termed the technological activities of firms in developing countries by 'technological capabilities', referring to the information and skills - technical, managerial and institutional - that allow firms to utilize equipment and technology efficiently.

The concept of 'innovation' is accordingly a much broader one than 'invention', which focuses on novelty and is applicable to frontier shifting new knowledge. Instead, innovation refers to the application of knowledge that is new to the firm and not necessarily new to its competitors, the market or the world. It incorporates a broad set of activities that individual enterprises undertake to gradually absorb knowledge and build upon existing knowledge necessary for efficient production and higher quality output. Minor and incremental rather than radical changes are at the heart of this innovation process in developing countries.

This broader definition of innovation has given rise to a debate on how to measure innovation in developing country firms. Measurement priority is placed on mechanisms of knowledge adoption and diffusion, which include human resources, linkages with other firms and non-firm organisations, the use of ICT, quality control systems, acquisition of embodied technology, and they should capture incremental and organisational change, which are key to growth in Latin America.

Micro level evidence of productivity in developing countries that measure the impact of technological learning activities is limited. Using data from Tanzanian firms, Goedhuys et al. (2008) found that the traditional technology variables, R&D and innovation output measures, turned out insignificant in explaining productivity differences. Some indirect technological variables such as foreign ownership, ISO certification and the educational level of the general manager seemed to affect productivity, but institutional factors, such as over-regulation, lack of government support, and a deficient health system, were equally important determinants.

2.4. Firm growth in developing countries

The theoretical and empirical literature on firm growth has concentrated mostly on examining the effects of firm size and age. The literature on firm growth in developing countries has also paid attention to the institutional barriers to firm development, such as poorly functioning financial markets and regulatory barriers. While financial constraints are also found to affect firm growth in OECD countries (Cabral and Mata, 2003, Beck et al., 2005) they may be even more severe in developing countries were financial markets are less developed and biased against small firms depriving them from necessary resources (Sleuwaegen and Goedhuys, 2002). With respect to regulatory constraints, Fisman and Svensson (2006) found corruption and taxation to hamper firm growth in Uganda.

3. The case of Brazil

3.1. Economic development in Brazil

An industrial power, ninth world GDP measured by purchasing power parity with the largest population in Latin America and the Caribbean, in the past few years Brazil has reached important economic, social and environmental advances, including macroeconomic stability and significant reductions in poverty.

Using a combination of state funding, foreign direct investment (FDI), and private sector investment, the country has expanded beyond agricultural commodities and low value-added manufacturing. Brazil has become a global competitor within the aerospace industry’s fastest growing sector, that of regional transport jets. Through joint ventures with multinational corporations (MNCs), the country also has developed information and communications technology (ICT) and software industries that serve domestic and regional markets. However, in other high-tech, high-growth sectors, Brazil is falling behind global competitors, particularly in Asia.

Sustaining growth is the major challenge for the Brazilian economy. Brazilian growth has remained close to half of the global and Latin American averages. Despite some advances in microeconomic and institutional reforms, and star performance by selected companies in selected areas, activity by the private sector in general remains stifled by various barriers and regulations that prevent the country from achieving its full growth potential. Bottlenecks include inadequate infrastructure, poor business climate, high tax rates, high cost of credit and rigid labour markets. The size of the government and its distorting impacts are also an obstacle, and the quality of governmental services in relation to expenditures remains relatively low compared to other countries. The government launched in 2007 a Growth Acceleration Plan to increase investment in infrastructure and provide tax incentives to encourage faster and more robust economic growth.

3.2. FDI and trade in Brazil

For Brazil, one of the legacies of import substitution has been a relatively closed economy with little international competition in many of its sectors. The country's level of trade as a percentage of GDP, is about half of China's. It is also lower than the Latin American average.

The Brazilian economy has a large domestic market where many sectors only compete locally. Those sectors that are not integrated into global competition face less pressure to increase productivity through innovation. This environment has also left many export sectors, aside from aerospace, falling behind their international competitors and lowering Brazil's market share across a range of technology-intensive goods. Average import tariffs are high in comparison with the OECD area. Therefore, there is scope for reducing tariff barriers to trade to facilitate access by the business sector to imported intermediate inputs and capital goods embodying more modern technologies.

Although Brazil, unlike other developing countries, does not seem to be particularly attractive from a labour cost/quality standpoint, FDI has continued to flow into the country, attracted by the large (potential) market. But the focus has shifted away from FDI coupled with technology transfer in technology-intensive sector to investments in the service sector. In part, this refocusing of FDI on services is simply a reflection of shifts within the Brazilian and global economy. However, technology transfer restrictions and limited IPR enforcement also have an impact on this shift. These tech transfer restrictions include licensing agreements with the government, which have helped protect specific industries such as aerospace, but have been harmful to most sectors. One technology-intensive industry example has been the computer sector, which was developed under import substitution but now faces heavy international competition from MNCs. Without technology transfer, the domestic computer industry operated on its own standards and software, which were innovating slowly compared to global competitors. As a result, the sector has not been able to compete effectively.

3.3. Innovation in Brazil

Brazil has made great strides in developing its innovation system. Brazil is Latin America's largest and most innovative economy, with over 1 percent of its GDP going to R&D. Brazil has exhibited particular strengths in selected technological fields, most notably aerospace and bio-ethanol, but also in deep-water oil drilling and agricultural technology for tropical climates. However, globally, Brazil ranks low in terms of both overall competitiveness and innovativeness. R&D funding has been repeatedly and severely impacted by the economic crises of the 80s and 90s. Moreover, business R&D funding as a percent of GERD is very low. This has left the country behind advanced economies, but also other developing countries, like China.

(i) Public R&D

Most of Brazil's R&D and almost all of the scientific breakthroughs are coming from the public sector. 80 percent of Brazilian researchers carry out their activities within public institutions (universities or research centres. Thanks to sustained public funding for R&D, Brazil has managed to increase its scientific performance. In two notable cases, aerospace and bio-ethanol, government input to research has helped Brazil to excel globally and to transfer its expertise abroad or domestically across institutions. Additionally, Brazil's public innovation funding is concentrated geographically. Sao Paulo receives a significant share of the public funding and financial support, followed by Rio de Janeiro, where a large number of the universities and research institutes are located.

Most universities have typically been teaching institutions with few links to Brazilian businesses. Reforming universities to be more connected with the industrial sector has been on the agenda of the Brazilian government for some time. Most of the recent expansion in the number of higher education degrees awarded is accounted for by private institutions, whose students tend to perform less well on the basis of standardised tests than those enrolled in public universities.

(ii) Private Sector

A mixed picture emerges of the private sector. The comparatively low number of patents awarded to Brazil is a reflection of the low commercialisation of innovation. The country has exceeded Latin America in total WIPO patents, but when R&D spending as a percentage of GDP is taken into to account, the country falls to below average. Domestic patents are predominately granted to state-owned enterprises rather than the private sector. MNCs are granted very few due to the costs and delays of the IPR structure along with the limited enforcement capability of the government.

Also the private sector R&D efforts are predominately limited to large firms in a few sectors. Only in a handful of industries, most notably aerospace, Brazil's innovative capabilities are able to compete with industrialised countries. While there are a growing number of technology-intensive, highly-productive small and medium businesses, many do not invest heavily in innovation and few export their goods to compete globally. Furthermore, process, rather than product, innovations account for the bulk of innovative activities in the business sector.

(iii)Barriers to innovation

A first barrier to effective R&D performance in Brazil is the limited number of science and technology programmes in tertiary education resulting in a shortage of highly skilled workers available for its technology-intensive industries. The percentage of students graduating from high school is still very low resulting in a lack of higher education graduates in general and limiting the level of workforce skills.

A second barrier is access to finance. Despite macroeconomic stabilisation since the mid nineties, the cost of capital still remains high in Brazil.

Another factor limiting the innovation potential is ICT usage. The Brazilian telecommunications equipment industry was initially a protected "infant industry" in Brazil. Trade barriers were erected to allow the industry room to grow. Government-sponsored R&D efforts in communications hardware and software helped to create a viable indigenous sector that was capable of serving the local market. Nevertheless, the use of ICT technologies is less widespread in Brazil than in countries with comparable development. (Szapiro, 2003; Mani, 2004).

Another relevant obstacle is the widespread confusion and lack of information among many companies regarding government-driven innovation initiatives in addition to tension regarding intellectual property rights.

(iv) Innovation Policy

To increase the involvement of the private sector, the government has instituted several financial incentives. Many are targeted at specific industries, such as aerospace and IT. There are, however, more generally available financial incentives [1].

While the country has lowered barriers that were left over from its previous import substitution policies, it has moved to protect and foster those technology sectors that thrived under the barriers. This has included regulations on joint ventures with multinational corporations and technology licensing agreements – meant to support innovative capacity building within Brazil.

During the economic recessions and crises of the 1990s, funding for science and technology programmes was severely cut (Cassiolato, 2003). The funding for innovation that was available to firms was misdirected to purchase capital equipment rather than for R&D.

The government attempted to compensate for its lack of direct R&D support by inviting foreign inflows of technology. That was largely successful; however much of that inward investment was used for merger and acquisition activity rather than to build indigenous capacity.

The Financing Agency for Studies and Projects (FINEP) is the lead agency offering support to innovation efforts within private industry, universities, and non-profits through loan and grant programmes (Rodrigues, 2002). The agency's current funding level is significantly lower than its counterparts' in other fast-growing developing countries, particularly the Asian tigers. In addition, the agency's continued focus on import substitution, and the large bureaucratic hurdles it has in place for funding, have left many small firms without access.

[1] These include the accelerated depreciation of machinery, equipment, devices and instruments, fittings, and tooling used in R&D; a 50 percent reduction in the industrial products tax payable on equipment or supplies purchased for use solely under the programme; accelerated amortisation of outlays made for acquisition of intangible goods tied to R&D; deduction of up to 4 percent of the income tax due on expenditures on technological and industrial R&D activities; and deduction as an operating expense of royalty, technical, and scientific assistance payments up to 5 percent of net income earned from the sale of goods produced with the technology for which such payments were made (Guasch, 2002; pg 343).

To address the issue of small firm innovation in the late 1990s, the federal government created a number of new programmes and initiatives targeting the small and medium enterprise (SME) sector. These programmes were designed to help SMEs with technological transfer and innovation through loans, venture capital, and training (Lemos, 2000). Several governmental organisations, including FINEP, the Ministry of Science and Technology, and the National Bank for Economic and Social Development supported these efforts; however there is no single coordinating agency. These efforts attempt to use technology to spur SMEs' productivity and exporting.

The national government long has sponsored vocational training programmes as a way to support worker re-education. These programmes have recently been changed to include more technical training and technology assistance.

(v) IPR

Brazil's intellectual property rights regime is above average as compared to Latin America and far behind the industrial countries, particularly the U.S. The Brazilian IPR institutions are slow to process patent applications and even slower to enforce IP laws. For international corporations, foreign patents require importers to pay a licensing fee if there is no local production involved with the product. While this has severely limited foreign patent holders, the main motivation has been to increase foreign direct investment and technology transfer opportunities by encouraging importers to invest in local production facilities.

4. Data, research questions and methodology

The empirical analysis uses the World Bank's Investment Climate Survey (ICS) data collected in Brazil in 2003. The data collection is part of a larger and ongoing program coordinated by the World Bank that implements Investment Climate Surveys in many countries using a harmonised master questionnaire. The objective of the ICS is to obtain firm level data that allow analysing the conditions for investment and enterprise growth in the country. As such, the many aspects of the business environment that influence the investment decisions and performance of the firms were tackled, in a number of sub-questionnaires. A set of questions was asked on the history of the firm, the background of the entrepreneur and manager, the acquisition and status of equipment and technology, the firm's human resource management, innovation activities, and institutional constraints to growth and investment. Survey data were collected through intensive interviews with owners and managers of firms.

The data set of Brazil contains information on 1642 manufacturing firms which represent a stratified random sample, stratified on the basis of size, sector and location. The firms are selected from nine sectors: food industries (CNAE[2] code 150), textiles (CNAE 170), clothing (CNAE 180), leather products (CNAE 190), chemical products (CNAE 240), machinery (CNAE 290), electronics (CNAE 320), auto-parts (CNAE 344), furniture (CNAE 361). The entire size spectrum of firms is represented. A majority of firms is from São Paulo and Minas Gerais, but in total 13 states are covered by the sample. These are Rio de Janeiro, Santa Catarina, Rio Grande do Sul, Paraná, Goiás, Mato Grosso, Ceará, Paraíba, Maranhão, Bahia,

[2] The CNAE (Classificação Nacional de Atividades Econômicas) is the Brasilian national classification which is closely linked to the ISIC (International Standard Industrial Classification) revision 3 and 3.1, at least up to the 2-digit level.

Amazonas. Within the selected sectors, the sample gives a fair representation of the total population with respect to the size and location dimension. More detailed information on the sample and sampling procedure can be found in World Bank (2005).

The survey collected data for the period 2000, 2001 and 2002. Additionally, the sales value was also asked for the year 1997, which permits investigating sales growth over a longer period of time: 1997-2002.

Due to missing values for some of the key variables, the number of firms used in our analysis is reduced to 1563, distributed over the different size classes and sectors as shown in table 1.

Insert table 1

Using firm level Brazilian data across industrial sectors and across states, we will analyse the firm, industry and regional characteristics that are able to explain the firms' innovation performance and its impact on firm growth. Table A1 in Appendix provides a description of all the variables used in the analysis.

- We can identify firm innovation strategies, on both the "make" and "buy" dimension. In the questionnaire, firms were asked about their major ways of acquiring new technology. As observed in many other developing countries and in line with the expectations, firms reported that the most important channel for new technology acquisition was by investing in machinery and equipment that embodied newer vintage technology, followed by in-house development of new technology. Other less frequently mentioned strategies consisted of hiring key personnel, sourcing from a parent company, licensing technology from other firms, developing technology in collaboration with clients or suppliers, or universities, or from trade fairs and study tours.

  We concentrate on the two major innovation strategies, consisting of acquiring new technology embodied in new machinery and equipment (BUY) and developing technology within the firm (MAKE). Since firms could report up to three important strategies, firms could also express to find both strategies important.

  Hence, we construct different exclusive categories for the firm's *innovation strategy*: firms that only report in-house development of technology (*MakeOnly*); firms that only have external technology acquisition embodied in machinery (*BuyOnly*); and firms that combine own development activities with embodied technology acquisition (*Make&Buy*) and finally firms that have no such innovation strategy of developing technology nor buying technology embodied in superior machinery and equipment (*NoMake&Buy*);

- We can link the technology "make" or "buy" strategy to the innovative performance of firms. We measure innovative performance by the introduction of a new production processes that substantially changed the way the main product is produced (process innovation) and/or the successful introduction of new products (product innovation), both over the three year period 2000-2002.

- Having analyzed the innovative strategies and performance of firms in a first step, the analysis will in a second step, analyse the impact of innovation on firm performance. We use as measure of firm performance, average annual sales growth over the period 1997-2002. Alternatively we also use growth over the 2000-2002 period.

- The dataset allows constructing a rich set of controlling factors. Beyond the typical firm size and age variables, as well as sectoral and regional classification, the dataset also allows identifying
    - the leading or lagging position of the firm in the technology and market competition;
    - as a crucial component of absorptive capacity, we can identify the human capital of the firm (both its work force as its management), which can be characterized by secondary and tertiary education levels; specialized technical versus general skills; we also can identify the use of ICT.
    - the financial constraints firms face in doing business
    - the exposure to international technology and competition, investigated through multiple channels: foreign ownership, exports, imports of components, competition from imports

The main disadvantage of the dataset is the restriction to a cross-section dimension only. The lack of a panel data structure of the dataset particularly restricts the growth part of the analysis.

5. Results of the empirical analysis

Before we present the results from the econometric analysis of firms innovative performance and growth, we first show some descriptive statistics on firm's innovative strategies, innovative performance and growth.

5.1. Descriptive statistics

Table 2 summarizes the information about the firm's **innovation strategies**, more particularly who *BUYs* and/or *MAKEs*. 61% of the sample firms acquire embodied technology externally. Somewhat less but still more than half of the sample firms (56%) relies on internal development. The most frequently observed innovation strategy is the combination of *Make&Buy* (34%). The exclusive use of external acquisition (*BUYonly*) is the second most frequently observed observation (27%), while 17% of the sample firms report *noMakeorBuy* activities as a major way to acquire technology. These are firms that resort to other less frequently observed ways for acquiring technology, such as those mentioned earlier (hiring key personnel, licensing, trade fairs, consultants, universities, clients, suppliers…) and do not mention embodied machinery and internal development of technology as important to them.

Insert table 2 here

When we split the total sample according to firm characteristics, we find very little differences on the occurrence of Make and/or Buy activities. The only strategy that stands out is the *NoMake&Buy* strategy, which is more likely to be chosen by firms with less international linkages, firms which are technology laggards, face less international competition, have less ICT uptake, are more financially constrained, and are smaller and younger (less than 5 years since establishment).

Table 3 analyses the **innovative performance** of the different innovative strategies. Two third of all firms report having introduced new processes in the observed period. Companies without a MAKE or BUY strategy are clearly less likely to be able to introduce new processes. Interesting to observe is the performance of the *MakeOnly* strategy, which is less performing as compared to an innovation strategy that uses embodied technology acquisition, exclusively or in combination with internal development. This is reminiscent of the importance of technology acquisition rather than own technology development as innovative strategy for firms in developing countries. There is some evidence in favor of complementarity between *Make* and *Buy*, since the highest success rate is observed for the *Make&Buy* strategy (76%). But this is only slightly higher than the performance of the *BuyOnly* strategy (74%).

On average, almost all companies report having introduced new products in the observed period, with very little difference between the different innovation strategies, with the exception of the *NoMake&NoBuy* strategy, which "only" has three quarters of these firms being able to introduce new products. The high frequency of reporting introductions of new products makes this variable not useful for analysis. This is why we concentrate the remainder of the analysis on innovative performance on process innovations only. In any case the successful introduction of product and process innovations is highly correlated: 94% of successful process innovators also introduced new products and 74% of firms with successful new product introductions also introduced new processes.

Insert table 3 here

Again when we look at the process innovation performance for different categories of firms, we find very little significant differences. There is some evidence that internationally oriented firms are more innovative performing (i.e. those exporting and those importing material from abroad). Also the technology leading firms and those with ICT uptake and less financially constrained score higher on innovative performance. Competition and absorptive capacity measures are not giving different innovative outcomes, as are firm size and age.

Table 4 analyses the performance of the different innovative strategies in terms of **sales growth** over the longest period we could measure 97-02. While on average firms reported a sales growth rate of 12%, there is surprisingly little variation across the different innovation strategies. Also there is no evidence for superior sales growth for successful process innovators, which on average realize a sales growth rate of 12%, equal to the total sample average.

Insert table 4 here

Also when splitting the sample according to innovation drivers, only weak effects are found. The descriptive statistics for subsample of firms show no large differences according to competition, international linkages, absorptive capacity. Firm size and age however are significant, with small and new firms more likely to have below median growth rates.

This first descriptive view of the data suggests

- the importance of embodied technology acquisition as an innovation activity, with also some support for complementing technology acquisition with in-house development (MAKE).

- a positive link between innovative activities and innovative performance, with a more favorable outcome for especially the BUY option (exclusively or in combination with MAKE). Innovative performance involves often a combination of product and process innovations. The most distinctive dimension is however process innovations.
- the link between innovation strategies and growth to be rather weak.

The next sections will detail which factors will turn out to be significant drivers in a multivariate analysis of innovative and growth performance.

5.2. Multivariate analysis results on innovative performance

In view of the extremely high reporting of successful product innovations and this across firm characteristics, we only focus on the successful introduction of process innovations as indicator of innovative performance. This is also consistent with other Brazilian evidence, using CIS-like surveys, which found process innovations to be the most common and relevant form of innovations.

Process innovation is modelled following a probit model, which relates the probability of being a process innovator to the characteristics of the firm (X) and the underlying innovation strategies (I). Our set of independent firm characteristics (X) includes the typical size, age, sector and regional dummies. Our main variables of interest are the set of innovation strategies (I): *MakeOnly*, *BuyOnly*, *Make&Buy*, with *NoMake&Buy* the reference category.

In addition other variables that influence innovative performance are included in the equation. These include the technology position of the firm in its market (T), the absorptive capacity in the firm (AC), foreign linkages and exposure (F), competitive pressure (C) and financial constraints (FIN) and are measured through various proxies as shown in table A1 in Appendix.

$$PROCESS_i^* = \alpha X_i + \beta I_i + \gamma T_i + \delta AC_i + \varepsilon F_i + \zeta C_i + \eta FIN_i + e_i$$

$$PROCESS_i = 1 \text{ if } PROCESS_i^* \geq 0$$

$$PROCESS_i = 0 \text{ if } PROCESS_i^* < 0$$

The results from the probit estimations on the likelihood of successful process innovations, using the total sample, reveal a strong and significant effect of innovative strategies on innovative performance. All innovative strategies, *MakeOnly, BuyOnly* and *Make&Buy*, have significantly positive coefficients, a result which is robust across alternative specifications. The size of the coefficients indicates a lower performance of the *MakeOnly* strategy as compared to the *BuyOnly* and *Make&Buy* strategy. The combination of *Make&Buy*, has the highest coefficient. This can be interpreted as evidence in favour of complementarity, but the difference with the *BuyOnly* strategy is only minimal. Technology leading firms have a significantly higher likelihood of successfully introducing new processes, while technology lagging firms have a significantly lower likelihood, suggesting no benefit for the latter of catching up.

When splitting the sample between technology leaders, technology laggards and average technology firms, interesting differences emerge on the significant effects of innovative strategies. The *MakeOnly* option is not significant for technology lagging firms. For these firms only technology acquisition is a significant option. The higher coefficient of *Make&Buy* nevertheless suggests that even these firms need some own development to be successful technology acquirers. For technology leading firms, the *MakeOnly* option is significantly positively related to innovative performance. But also, and even more so, is the technology acquisition option. Somewhat surprising, the most interesting strategy seems the *BuyOnly* option. Apparently, having a technology leading position also makes it easier to be an efficient technology acquirer, without the need for internal further development, at least in Brazilian manufacturing.

Financial constraints are a significant factor in the innovation process. Companies which are less financially constrained, having overdraft facilities, are more successful innovators. This factor is however not relevant for technology leading firms. It is only the weaker technology firms for whom access to finance becomes more important. But although the coefficient is highest for the technology lagging firms, it is not significant, suggesting a larger heterogeneity in effectiveness of access to finance in this group of firms. Further research is needed to examine which characteristics help to pin down this effect.

On the different measures for absorptive capacity, the results suggest that is not the level of tertiary education of the work force of the company that matters, but rather the level of secondary education. A general manager with graduate or postgraduate education even adds negatively to innovative performance, an effect which is even significant in the overall sample. Too highly educated personnel works especially detrimental on innovative performance for technology lagging firms. To be examined further whether this education level holds differently for technical versus non-technical skills.

Our variables on international linkages as well as on competition, all fail to turn out significantly in explaining innovative performance, also in various alternative specifications. This clearly needs to be examined in further detail, but is suggestive of the still important influence of a "closed-economy, protection-of-local-firms" perspective in Brazil's innovation policy.

Insert table 5 here

5.3. Multivariate analysis results on growth performance

In line with the literature on firm growth (Evans, 1987, Sleuwaegen and Goedhuys, 2002), the basic empirical model for the growth equation is a general growth function g in size (S) and age (A):

$$g = \frac{S_{t'}}{S_t} = g(S_t, A)$$

where $S_{t'}$ and S_t are the size of a firm in end period t' – here 2002- and in beginning of period t - 1997 - respectively and A is the age of the firm in 2003.

This functional relationship is augmented with additional variables that we expect to have a direct impact on growth. Our major variable of interest is the effect of innovative performance on growth, i.e. the effect of process innovation (PROCESS). In addition, we also add variables to capture the technological position of the firm (T), competition (C), access to finance (FIN), and various measures for foreign linkages (F) and one for human capital (AC).

We approximate the growth function g through a second order logarithmic expansion of a generalised function relating growth to size and age and we add the growth shifting variables. The resulting estimating equation corresponds to the following form:

$$\frac{\log(S_{t'})-\log(S_t)}{d} = a_0 + a_1\log(S_t) + a_2[\log(S_t)]^2 + a_3\log(A) + a_4[\log(A)]^2 + a_5\log(S_t)*\log(A) + a_6 PROCESS + a_7 T + a_8 C + a_9 FIN + a_{10} F + a_{11} AC$$

where d stands for the number of years over which growth is measured and a are coefficient vectors.

In line with this model, our dependent variable corresponds to an average annual sales growth rate over de period 1997-2002. The explanatory variables are as defined in table A1 in Appendix and include PROCESS; TECHLEADER and TECHLAGGARD for the technology position of the firm; COMPIMP, COMPPRESSF and COMPPRESSD for competition; the OVERDRAF variable to consider financial constraints; MNE and EXPORTBEFORE for international linkages and GMHIGH for the quality of human capital.

Our major variable of interest is the effect of innovative performance (PROCESS) on sales growth. As a first test, we simply include the PROCESS dummy in the growth equation. The coefficient of PROCESS may however be badly estimated, because of endogeneity: faster growing firms may have a larger incentive and capacity to introduce new process innovations. Unfortunately our dataset does not allow a sufficiently lagging of the PROCESS variable or forwarding of the growth results. Furthermore, unobserved firm-specific effects in the innovation performance regression can cause the coefficient of PROCESS in the growth regression to be biased, if they also enter the growth error term, as an unobserved explanatory factor for growth as well. Panel data would allow including firm fixed effects. Our data set does however not permit a panel data structure. We use a two step procedure in an attempt to improve our estimation while correcting for the potential biases due to endogeneity and unobserved heterogeneity. The two-step procedure uses the predicted values of the innovative performance as instrument in the growth regression. We use a 2SLS procedure, where we use as instruments for PROCESS variables used previously (sector & region dummies, firm size & age, the innovation strategies (I), technology leading/lagging, overdraft, skills, email & competition from imports). Alternatively, we also include the predicted values of PROCESS from the probit analysis using the same set of variables as regressors.

Insert table 6 here

Our results on growth performance (using a basic OLS) confirm the significance of firm age and size effects. Small and young firms grow significantly faster in Brazil than larger and older firms, but with significant evidence of non-linearity in the size and age effects, as well as a significant negative interaction effect, indicating that old, large firms grow more slowly. Also significant is the effect of financial constraints, with access to overdraft facilities stimulating firm growth. In contrast to the results from innovative performance, having a graduate or post-graduate general manager pays off in terms of higher sales growth performance.

While international linkage variables failed to affect significantly innovative performance, they do affect firm's growth performance: companies with foreign shareholders and/or foreign sales have a higher growth rate. There is clear evidence that exposure to competition from abroad is an efficiency enhancing device, resulting in higher sales growth: firms facing competition from foreign firms to reduce costs are also more likely to have higher sales growth. The same cannot be said for competition from domestic competitors, which fails to have a positive effect on sales growth.

Our main variable of interest in the growth equation is the process innovation performance of the company. Do firms that introduce successfully new process innovations also reap the benefits of this in terms of larger sales growth? In the basic specification, where we simply include PROCESS in the OLS growth specification, the results are positive, but insignificant. The only evidence in favour of the importance of technology for growth comes from the significantly lower growth performance of technology lagging firms.

However, in the 2SLS results, when we properly instrument PROCESS, the coefficient becomes significantly positive, indicating that firms which successfully introduced new process innovations also have a better sales growth performance, all else equal. A similar significantly positive effect shows up if we use the predicted PROCESS procedure. The 2SLS procedure leaves all the other results unchanged.

Insert table 8 here

6. Conclusions

Using data from the World Bank's Investment Climate Survey (ICS) data collected in Brazil in 2003 for manufacturing sectors, this paper tries to contribute to the literature on technological progress and development by bringing on board a micro-econometric perspective on the factors determining innovative performance and firm growth. Our focus on Brazil allows analysing the case of a mid-income country in fast development, where the interplay between diffusion (buy) and creation (make) of new technologies, is centrepiece for sustaining growth. With a mixed legacy of protectionism and international openness, it is also an interesting case to analyse the importance of international linkages for innovation and growth.

Although the results are still interim and require further analysis, there are already a number of interesting findings which appear to be robust across several specifications. First, technology is important for the performance of Brazilian firms. This is supported from the lower performance of technology lagging firms, both on innovative performance (as measured by successful process innovations) as well as on sales growth. Also the positive impact of innovative performance on sales growth, at least when innovative performance is properly instrumented, supports this assertion. Like in many developing countries, also in Brazil, process innovations occur mostly through technology acquisition, by acquiring know-how embodied in machinery and equipment. The option of only relying on internal development is less performing. There is some evidence in favour of higher innovative performance if firms combine acquiring technology with internal development, but the evidence is not strongly in favour of a combined strategy. There is nevertheless evidence of the importance of absorptive capacity and skills in explaining innovative performance. But somewhat surprisingly, it does not require a tertiary skilled workforce to be a successful process innovator in Brazil, which could even work negatively. Secondary skilled workers suffice for innovative performance in Brazil. These results are perhaps a bit surprising, but reminiscent of the debate in Brazil on the quality and mismatch in higher education. Another robust factor driving innovative and growth performance, is the access to finance, both for innovative performance as well as sales growth performance. This supports policy interventions to alleviate the financial constraints, by improving financial market functioning and/or providing financial incentives. The survey provides information that can be used to analyse the effectiveness of government incentives to improve innovative and growth performance. Finally, our results on international linkages are somewhat mixed. International openness is important for stimulating firm growth performance, but this openness works particularly through competition as an incentivizing device for cost improvements, stimulating firm growth, but not necessarily as a mechanism for technology absorption improving innovative performance. Again this can be related to the specifics of the Brazilian case, which has for a long time protected local champions in its innovation policy.

But before more robust policy conclusions can be drawn from the analysis, further research is needed on the factors which determine the choices of innovative strategies, make and/or buy, and their effects on performance. Beyond a further extension of the set of determining factors, also the set of performance indicators needs to be extended, to include also productivity growth, inter alia. Fortunately, the survey data provide a rich set of firm characteristics that are not yet fully exploited in the current analysis. Also, the results have indicated that after including for a large set of firm characteristics, sectoral and regional effects remain significant. Trying to better understand which sectoral and regional characteristics are important in interaction with firm characteristics remains on the research agenda. What is clear is that the specifics of Brazil are important to better understand the results and to be able to improve on the analysis.

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Table 1: composition of the sample

	Small 10-29 workers	*Medium 30-99 workers*	*Large 100+*	*All firms*
Food	15	33	72	120
Textiles	21	27	54	102
Clothing	95	203	126	424
Leather	26	78	56	160
Chemicals	12	32	34	78
Machinery	43	61	74	178
Electronics	12	39	23	74
Auto-parts	16	42	68	126
Furniture	76	136	89	301
Total	316	651	596	1563

Table 2: Frequency of occurrence of innovation strategies

Total	**100%**
No Make/No Buy	17%
Make Only	22%
Buy Only	27%
Make & Buy	34%

Table 3: Innovative performance of innovation strategies

	% process-innovators	**% product-innovators**
No Make/No Buy	23%	76%
Make Only	61%	97%
Buy Only	74%	98%
Make & Buy	76%	98%
Total	**66%**	**94%**

Table 4: Sales growth performance of innovation strategies

	Sales growth 97-02
No Make/No Buy	10%
Make Only	12%
Buy Only	13%
Make & Buy	11%
Total	**12%**

Table 5: Results of the probit analysis explaining process innovation (PROCESS)

	All firms	*Techn. leaders*	*Techn. laggards*
ltl00	0.057	0.180*	0.094
	(0.039)	(0.092)	(0.124)
lfirmage	-0.114*	-0.214	0.112
	(0.062)	(0.140)	(0.181)
make	0.407***	-0.049	0.839***
	(0.115)	(0.302)	(0.310)
buy	0.819***	0.508*	1.379***
	(0.113)	(0.302)	(0.290)
makeandbuy	0.875***	0.716**	1.107***
	(0.110)	(0.291)	(0.287)
techleader	0.386***		
	(0.092)		
techlaggard	-0.197**		
	(0.098)		
overdraf	0.197**	0.072	0.372
	(0.083)	(0.217)	(0.238)
lfhigh	0.024	-0.435	-3.329**
	(0.403)	(0.745)	(1.680)
lfsec2	0.369**	1.210***	-0.277
	(0.180)	(0.460)	(0.532)
gmhigh	-0.176**	-0.300	-0.328
	(0.080)	(0.209)	(0.219)
forfirmexper	-0.166		
	(0.138)		
ltotexper	0.066	0.161	-0.384*
	(0.066)	(0.162)	(0.208)
email	0.185	0.077	0.274
	(0.137)	(0.472)	(0.321)
mne	-0.184	-0.826**	
	(0.194)	(0.374)	
directexport	0.009	-0.345	0.187
	(0.096)	(0.220)	(0.331)
impmaterial	0.059	0.015	0.021
	(0.077)	(0.196)	(0.228)
compimp	0.137	0.300	0.492
	(0.114)	(0.299)	(0.325)
comppressf	0.086	0.547	0.175
	(0.127)	(0.367)	(0.338)
comppressd	0.056	0.171	0.261
	(0.076)	(0.189)	(0.217)
Constant	-0.716***	-0.147	-1.383**
	(0.245)	(0.701)	(0.610)
Observations	1563	365	236

The estimation includes eight sector dummies and 12 geographical location dummies. Standard errors in parentheses; *significant at 10%; ** significant at 5%; *** significant at 1%

Table 6: Firm sales growth (SGR97-02): results from OLS

	All firms	*Techn. leaders*	*Techn. laggards*
lsales97	-0.315***	-0.494***	-0.253**
	(0.030)	(0.060)	(0.102)
slsales97	0.009***	0.014***	0.005
	(0.001)	(0.002)	(0.004)
Lfirmage	-0.129**	-0.358***	-0.358*
	(0.063)	(0.126)	(0.189)
Slage	0.077***	0.071***	0.069***
	(0.009)	(0.017)	(0.026)
sales97age	-0.021***	-0.004	-0.003
	(0.004)	(0.009)	(0.015)
process	0.004	0.021	0.012
	(0.016)	(0.040)	(0.038)
techlaggard	-0.059***		
	(0.020)		
techleader	0.026		
	(0.017)		
overdraf	0.063***	0.049	0.029
	(0.017)	(0.037)	(0.046)
mne	0.241***	0.151**	0.255
	(0.039)	(0.076)	(0.228)
exportbefore	0.105***	0.036	0.165*
	(0.024)	(0.047)	(0.093)
gmhigh	0.073***	0.086**	0.019
	(0.015)	(0.034)	(0.039)
compimp	0.027		
	(0.022)		
comppressf	0.072***		
	(0.025)		
comppressd	0.013		
	(0.015)		
Constant	3.014***	4.653***	3.077***
	(0.233)	(0.468)	(0.697)
Observations	1400	336	216
R-squared	0.41	0.48	0.48

The estimation includes eight sector dummies and 12 geographical location dummies. Standard errors in parentheses; *significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: Firm sales growth (SGR97-02): results of the 2SLS estimation (col.1-2) and the IV estimation (column 3-4)

	Process 2sls first stage	*sgr9702* 2sls	*process*	*sgr9702* All firms
lsales97	0.077	-0.323***		-0.304***
	(0.051)	(0.031)		(0.028)
slsales97	-0.003**	0.010***		0.009***
	(0.002)	(0.001)		(0.001)
lfirmage	0.098	-0.143**	-0.058	-0.039
	(0.107)	(0.066)	(0.049)	(0.065)
slage	-0.050***	0.085***		0.055***
	(0.015)	(0.010)		(0.010)
sales97age	0.010	-0.023***		-0.018***
	(0.008)	(0.005)		(0.004)
pprocess				0.253***
				(0.059)
process		0.155**		
		(0.070)		
techleader	0.143***	0.004	0.387***	-0.006
	(0.029)	(0.021)	(0.091)	(0.018)
techlaggard	-0.076**	-0.043*	-0.196**	-0.032
	(0.035)	(0.022)	(0.098)	(0.020)
overdraf	0.065**	0.051***	0.208**	0.039**
	(0.029)	(0.018)	(0.082)	(0.017)
gmhigh	-0.025	0.075***	-0.200***	0.085***
	(0.026)	(0.016)	(0.077)	(0.015)
mne	-0.008	0.243***		0.245***
	(0.067)	(0.041)		(0.038)
exportbefore	-0.001	0.103***		0.102***
	(0.041)	(0.025)		(0.023)
comppressf	0.039	0.071***		0.059**
	(0.043)	(0.026)		(0.024)
comppressd	0.013	0.011		0.013
	(0.026)	(0.016)		(0.015)
ltl00			0.053	
			(0.035)	
make	0.140***		0.412***	
	(0.041)		(0.115)	
buy	0.275***		0.820***	
	(0.039)		(0.113)	
makeandbuy	0.274***		0.881***	
	(0.038)		(0.110)	
lfhigh	0.029		-0.022	
	(0.138)		(0.394)	
lfsec2	0.064		0.359**	
	(0.061)		(0.178)	
email	0.063		0.189	
	(0.048)		(0.137)	
compimp	0.034		0.143	
	(0.038)		(0.109)	
Constant	-0.340	3.000***	-0.629***	2.668***
	(0.0395)	(0.240)	(0.220)	(0.228)
Observations		1400	1564	1363
R-squared		0.37		0.42

The estimation includes eight sector dummies and 12 geographical location dummies. Standard errors in parentheses; *significant at 10%; ** significant at 5%; *** significant at 1%

Appendix

Table A1: Definition of variables

SGR9702	Average annual sales growth over the period 1997-2002, calculated by (ln(sales2002) – ln(sales1997))/5
PROCESS	=1 if the firm introduced new technology that has substantially changed the way the main product is produced, in 2000-02.
Firm characteristics (X)	
LFIRMAGE	Age of the firm, in logarithmic terms
LTL00	Size of the firm, measured by number of employees in 2000, in log.
Innovation strategy (I)	
MAKEOnly	=1 if firm reports in-house development as major way of acquiring new technology, not embodied in machinery
BUYOnly	=1 if firm reports new technology embodied in machinery as major way of acquiring new technology, not developed in-house
MAKEandBUY	=1 if firm reports both in-house development and embodied in machinery and equipment as major ways of acquiring new technology
The technology position of the firm in its market (T)	
TECHLEADER	=1 if the firm reports that his technology is more advanced than that of its main competitors
TECHLAGGARD	=1 if the firm reports that his technology is less advanced than that of its main competitors
Absorptive capacity (AC), as measured through various proxies:	
LFHIGH	Proportion of the labour force with higher education [0,1]
LFSEC2	Proportion of the labour force with secondary education as highest level attained [0,1]
GMHIGH	Dummy =1 if the firm has a general manager with a graduate or postgraduate degree or diploma of tertiary college
LTOTEXPER	Total number of years of experience of the manager working in this industry, in log. terms
EMAIL	Dummy =1 if the firm uses a email to interact with clients and suppliers
Foreign linkages (F)	
FORFIRMEXPER	=1 if the manager has previously acquired working experience in the same industry, in a foreign firm
MNE	Dummy =1 if the firm's principal shareholder is a foreign company
DIRECT EXPORT	=1 if the firm directly exports
IMPMATERIAL	=1 if the firm imports directly or indirectly part of its inputs or raw materials
Competition (C)	
COMPIMP	=1 if for the firm's main product the main competitor is an imported product
COMPPRESSF	=1 if firm reports that the most important influence/pressure to reduce production costs are foreign competitors
COMPPRESSD	=1 if firm reports that the most important influence/pressure to reduce production costs are domestic competitors
Financial constraints (FIN)	

OVERDRAFT	=1 if the firm has an overdraft facility with a formal bank